DRAFT April 4, 2016

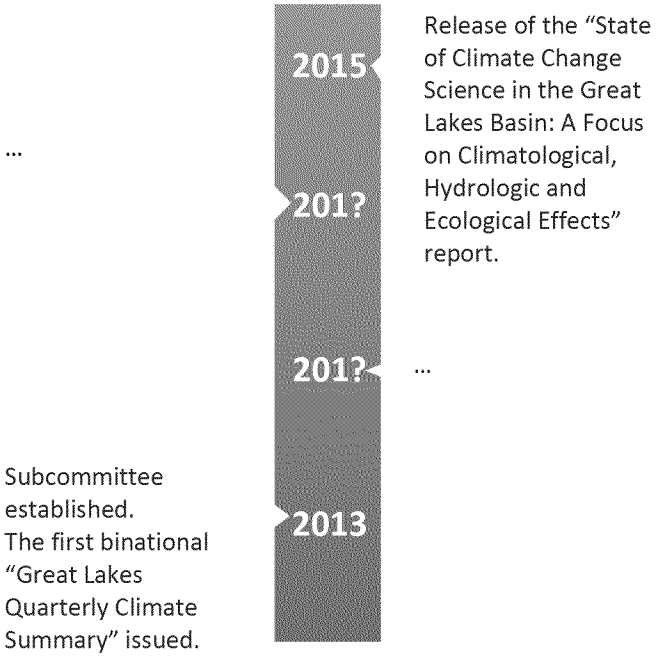
PROGRESS REPORT OF THE PARTIES
CLIMATE CHANGE IMPACTS ANNEX CHAPTER

OVERVIEW

Climate change is an exacerbating stressor, which challenges the health of our Great Lakes ecosystems and the communities they support. Current climate change concerns relate to greater fluctuations and possibly lower water levels across the Great Lakes region, rising lake temperatures and associated impacts on existing aquatic species and historic land covers (i.e., wetland loss) as well as possible introductions of non-native species (SOLEC, 2011 – www.binational.net/2011/10/16/sogl-edgl-2011).

Recognizing that climate change has an impact on the quality of Waters of the Great Lakes, Canada and the United States incorporated a new annex in the 2012 GLWQA to address this issue, through which both governments commit to coordinate efforts to identify, quantify, understand, and predict the climate change impacts on the water quality of the Great Lakes and to share information broadly with Great Lakes resource managers to proactively address those impacts. A key activity of this annex in the first three years was a synthesis of available science on the observed and projected impacts of climate change in the Great Lakes Basin.

PROGRESS TOWARD MEETING GLWQA COMMITMENTS



[Could possibly insert images of CCI Science Report and first issue of Outlook (perhaps need some other graphical representation other than screen shorts of 1st pages of these reports) on this 1st pg.]

This annex is implemented by the Climate Change Impacts Annex Subcommittee, co-led by Environment

Canada and the United States Environmental Protection Agency. Organizations on the subcommittee include: [insert logos]

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BINATIONAL ACTIONS TAKEN FOR KEY COMMITMENTS

Coordinate binational climate change science activities (including monitoring, modeling and analysis) to quantify, understand, and share information that Great Lakes resource managers need to address climate change impacts on the quality of the Waters of the Great Lakes and to achieve the objectives of this Agreement.

- In June 2013, Canada and the United States initiated the development of the first binational quarterly newsletter focusing on climate impacts and outlooks for the Great Lakes region. The "Great Lakes Quarterly Climate Summary" issues (www.binational.net/category/a9/qcio-btsc) provide a quick and easy to understand binational overview of the latest season's weather and water level conditions, weather and water level-related impacts and an outlook for the upcoming quarter. These Quarterly Climate Summaries are produced by U.S. and Canadian experts for use by managers and practitioners at federal, state, provincial, regional, and local scales as well as stakeholders and the general public.

- A series of webinars were conducted in 2014 to present information on climate change in the Great Lakes, based on the best available peer-reviewed science, to Annex Co-Leads and their Subcommittees, as well as other interested parties such as the Council for Great Lakes Industries. Webinars were provided for Annex Co-Leads and their Subcommittees specifically to enhance their broad understanding of climate information and to discuss the type of climate change information they would require to assist their annexes' implementation, and would help focus the work under the Climate Change Impacts Annex Subcommittee to provide more tailored climate change information.

- In December 2015, a "State of Climate Change Science in the Great Lakes Basin: A Focus on Climatological, Hydrologic and Ecological Effects" report was released, which synthesizes the state of climate change impacts in the Great Lakes Basin and identifies key knowledge gaps. The Executive Summary and further information about this work is available at [insert binational.net link]. The 2015 State of Climate Change Science in the Great Lakes Basin report supports various commitments under the Climate Change Impacts Annex and will be used for further discussions with Annex Co-Leads and their Subcommittees and inform future work of the Climate Change Impacts Annex Subcommittee.

Enhance monitoring of relevant climate and Great Lakes variables to validate model predictions and to understand current climate change impacts.

- A growing ensemble of in situ measurements – including offshore eddy flux towers, buoy-based sensors, and vessel-based platforms – are being deployed through an ongoing binational collaboration to reduce uncertainties in the Great Lakes water balance, provide a more robust basis for short- and long-term projections, and fill a significant gap in over-lake flux measurements, including evaporation and water temperatures, and related meteorological data. This initiative, known as the Great Lakes Evaporation Network (GLEN) is supported through a

consortium of researchers from Environment and Climate Change Canada and the National Oceanic and Atmospheric Administration, the University of Michigan, Northern Michigan University, the University of Colorado, Limno-Tech and the Great Lakes Observing System (GLOS).

DOMESTIC ACTIONS TAKEN

Develop and improve regional scale climate models to predict climate change in the Great Lakes Basin Ecosystem at appropriate temporal and spatial scales.

Link the projected climate change outputs from the regional models to chemical, physical, biological models that are specific to the Great Lakes to better understand and predict the climate change impacts on the quality of the Waters of the Great Lakes.

- Canada continues to support the development of coupled atmospheric-land-ocean models for the Great Lakes - St. Lawrence River system that can be integrated with Regional Climate models to evaluate the hydrometeorological impacts of climate change.
- A coordinated evaluation of the impacts of climate change on the levels and flows of the St. Lawrence River from 1961-2100 is being undertaken through a collaborative of agencies including Fisheries and Oceans Canada, Hydro-Quebec, Centre of Water Expertise of Quebec, OURANOS and Environment and Climate Change Canada. Climate change will modify the flow of water into the St. Lawrence River (from Lake Ontario, the Ottawa River, and tributaries) and the level of the Great Lakes. These two factors will lead to changes in both the average and extreme levels in the St. Lawrence River. The anticipated impacts include erosion or deposition along the river banks, navigation impacts, and impacts to drinking water intakes. A major focus of this project is improving the analyses of the routing of Ottawa River flows so that Great Lakes and St. Lawrence River models can be linked.

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- Environment and Climate Change Canada (ECCC) collects data from a network of approximately 1300 surface weather and climate observing sites across the country. These sites include weather stations owned by ECCC, NAV CANADA, National Defence, along with volunteer climate stations. The majority of these sites are automated observing platforms which report year round, 7 days a week, 24 hours a day. The Water Survey of Canada is the national authority responsible for the collection, interpretation and dissemination of standardized water resource data

and information in Canada. In partnership with the Province of Ontario, the Water Survey of Canada operates approximately 440 active hydrometric gauges in the Canadian portion of the Great Lakes-St. Lawrence River Basin. The Science and Technology Branch of ECCC supports the operation of three evaporation stations at Stannard Rock on Lake Superior, Long Point on Lake Erie and Simcoe Island on Lake Ontario as part of the Great Lakes Evaporation Network.

- Multiple methods and estimates of Great Lakes runoff are now available from various federal agencies in Canada and the United States and a comprehensive evaluation and coordination of runoff estimates is necessary. The Great Lakes Runoff Inter-comparison Project (GRIP) was initiated as a binational collaboration aimed at assessing a variety of models currently used (or that could readily be adapted) to simulate basin-scale runoff to the Great Lakes. The Great Lakes Runoff Inter-comparison Project for Lake Ontario (GRIP-O) was initiated by ECCC in fall 2013. The project compared different hydrologic models in their ability to estimate Lake Ontario's direct incoming runoff. The results highlight the different models' weaknesses and strengths, in order to assess which model to use as a function of the targeted application and experiment settings, with the more general goal to improve Lake Ontario's runoff simulation by identifying and fixing some of the model weaknesses.

Develop and improve analytical tools to understand and predict the impacts, and risks to, and the vulnerabilities of, the quality of the Waters of the Great Lakes from anticipated climate change impacts.

- The Canadian Precipitation Analysis (CaPA) is an operational near real-time gridded precipitation product from Environment and Climate Change Canada available since April 2011 for North America. The CaPA has generated a lot of enthusiasm in the Great Lakes-St. Lawrence River area due to its unique capability of capturing some of the precipitation features that are specific to the Great Lakes-St. Lawrence River region, in particular the effects that the lakes have on the precipitation patterns, something that is very difficult to catch with the existing precipitation gauging network. A project was initiated in 2015 to provide the foundation for extending CaPA back to 1983.

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- The National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Lab (GLERL) brought together several different modeling and observational approaches to study climate change in the Great Lakes basin. The modeling activity consisted of further development and application, specifically for our lake-dominated region, of three coupled atmosphere-lake-land regional climate models: the Coupled Hydrosphere-Atmosphere Research Model (CHARM, based on the Regional Atmospheric Modeling System, RAMS) at NOAA/Great Lakes Environmental Research Laboratory, the Regional Climate Model version 4 (RegCM4) at the University of Wisconsin, and the Weather Research and Forecasting Model (WRF) at the University of Maryland; along with development and testing of a version of the Finite Volume Coastal Ocean Model (FVCOM) with enhancements for simulation of ice (FVCOM-Ice) and lower trophic level ecology in the form of a nutrient-phytoplankton-zooplankton-detritus (NPZD) model component.

Enhance monitoring of relevant climate and Great Lakes variables to validate model predictions and to understand current climate change impacts.

- In 2013, the Lake Superior National Estuarine Research Reserve established a new Sentinel Site located in Pokegama Bay, Lake Superior. With funding support from NOAA, this Sentinel Site included weather/meteorological station, water quality sonde, surface elevation tables, permanent vegetation transects, geodetic vertical referencing benchmarks, and an acoustic doppler current profiler installation. This site is now recording monthly water quality sampling for nutrients and chlorophyll. The primary goal is to understand sediment movement and the consequence of sediment movement to marsh sustainably under the expectation of the increased frequency and intensity of storm events.
- The National Oceanic and Atmospheric Administration's (NOAA) Great Lakes Environmental Research Lab (GLERL) has been exploring the relationships between ice cover, lake thermal structure, and regional climate for over 30 years through development, maintenance, and analysis of historical model simulations and observations of ice cover, surface water temperature, and other variables. Weekly ice cover imaging products produced by the Canadian Ice Service started in 1973. Beginning in 1989, the U.S. National Ice Center produced Great Lakes ice cover charts that combined both Canadian and U.S. agency satellite imagery. These products are available at GLERL through the Coastwatch program (www.coastwatch.glerl.noaa.gov), a nationwide NOAA program within which the GLERL functions as the Great Lakes regional node.
- Currently, there is year-round monitoring infrastructure dedicated to understanding off-shore processes that impact Great Lakes ecosystem health. Beginning in Fiscal Year 2015, the National Oceanic and Atmospheric Administration's (NOAA) Great Lakes Environmental Research Lab (GLERL) (with funding support from the NOAA Coastal Storms Program) is seeking to fill these data gaps through a two-phased approach. First, the team will deploy and manage data from vessel- and buoy-based sensors to improve understanding of over-water meteorology, evaporation, and water temperature in the Great Lakes. Second, the project will also focus on data analysis, system validation, and model assimilation to improve access to and understanding of the acquired data.

Develop and improve analytical tools to understand and predict the impacts, and risks to, and the

vulnerabilities of, the quality of the Waters of the Great Lakes from anticipated climate change impacts.

- The National Oceanic and Atmospheric Administration's (NOAA) Office for Coastal Management developed and released the Lake Level Viewer (www.coast.noaa.gov/llv) for the U.S. portion of the Great Lakes basin in 2014. This tool helps users visualize lake level changes that range from six feet above to six feet below historical long-term average water levels in the Great Lakes, along with potential shoreline and coastal impacts. Communities can use this information to determine what preparations make the most sense in planning for water level change scenarios. Preparations might include zoning restrictions, infrastructure improvements, and habitat conservation. As a result of this work and product delivery, Digital Elevation Models are now available for each Lake Basin and the associated topographic and bathymetic data are being served on NOAA's Digital Coast.
- The National Oceanic and Atmospheric Administration's (NOAA) Great Lakes Environmental Research Lab (GLERL) developed and released a basin wide Water Level Dashboard in 2014 (www.glerl.noaa.gov/data/dashboard/GLHCD.html). The Dashboard is a dynamic graphical interface for visualizing projected, measured, and reconstructed surface water elevations on the earth's largest lakes. This interface also reflects relationships between hydrology, climate, and water level fluctuations in the Great Lakes.

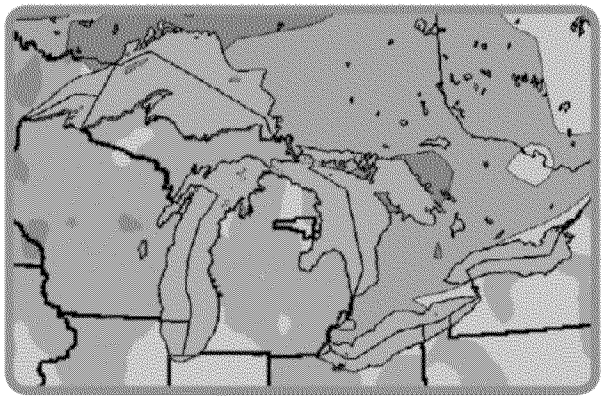
Coordinate binational climate change science activities (including monitoring, modeling and analysis) to quantify, understand, and share information that Great Lakes resource managers need to address climate change impacts on the quality of the Waters of the Great Lakes and to achieve the objectives of this Agreement.

- The National Oceanic and Atmospheric Administration's (NOAA) National Center for Environmental Information produces an annual "State of the Climate" report (www.ncdc.noaa.gov/sotc). This report provides a collection of monthly summaries recapping climate-related occurrences on both a global and national scale.
- The National Park Service released a Climate Change Scenario Planning Workshop Summary. This report summarizes outcomes from a two - day scenario workshop for Apostle Islands National Lakeshore, Wisconsin (APIS). The primary objective of the session was to help senior leadership make management and planning decisions based on up - to - date climate science and assessments of future uncertainty. The session was also designed to assess the effectiveness of using regional - level climate science to craft local scenarios; and provided an opportunity to introduce scenarios to participants and further their capabilities in scenario practice.

El Nino Impacts and Outlook - October/November 2015

Graphics:

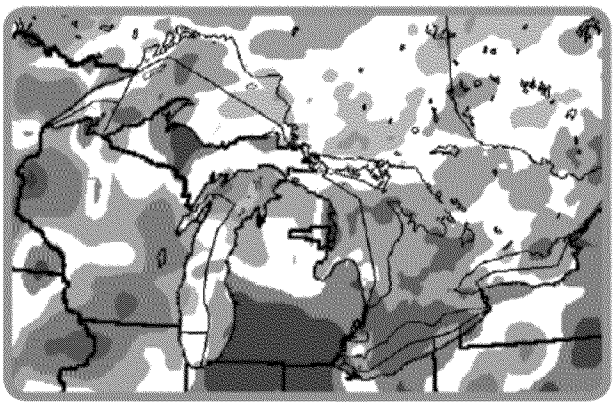
Sources: GL Climate Outlook – Fall 2015



Sept-Nov 2015 Air Temp: Departure from Normal

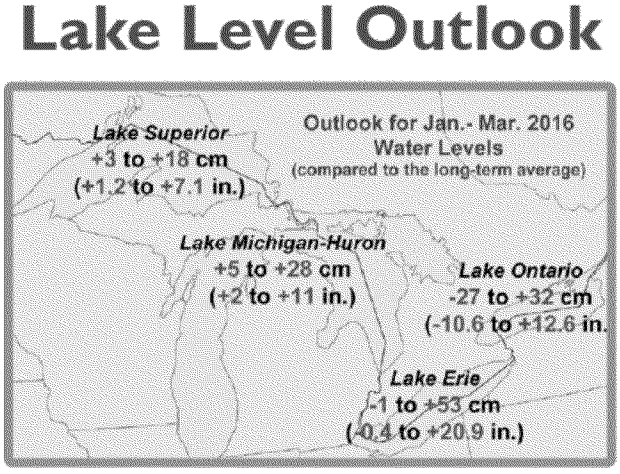
°C -5 -4 -3 -2 -1 -0.5 0.5 1 2 3 4 5

°F -9 -7.2 -5.4 -3.6 -1.8 -0.9 0.9 1.8 3.6 5.4 7.2 9

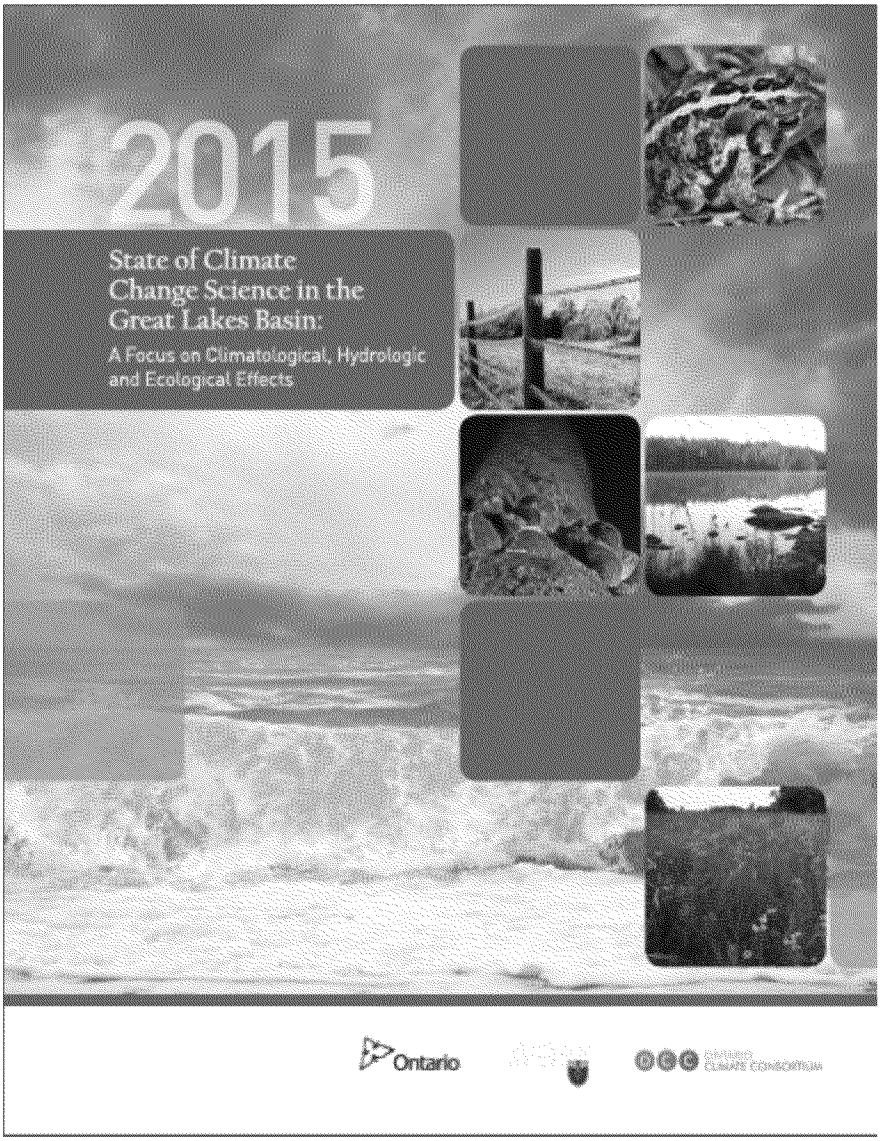


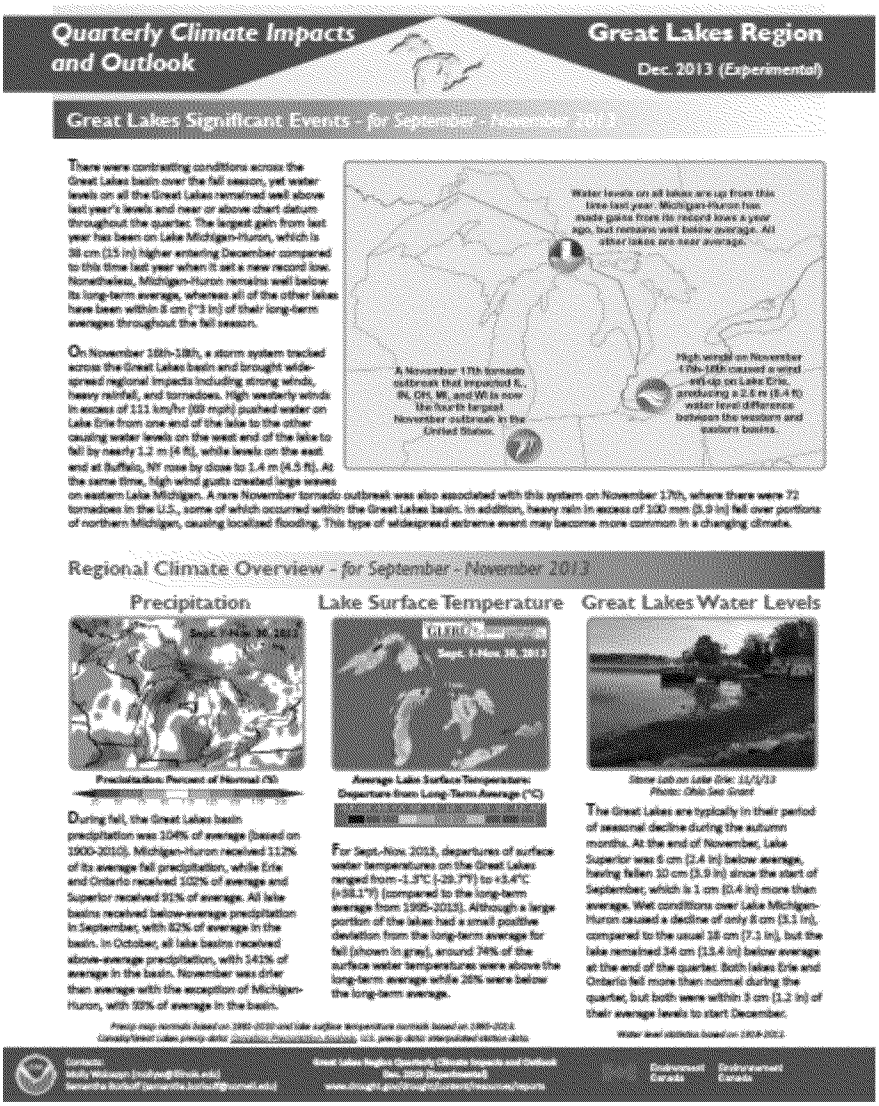
Sept-Nov 2015 Precip: Percent of Normal (%)

25 50 75 90 110 125 150 175 200



Potential range for water levels for Jan-Mar 2016 compared to the long-term average (1918-2014).


2015
State of Climate Change Science in the Great Lakes Basin:
A Focus on Climatological, Hydrologic and Ecological Effects
Ontario



Quarterly Climate Impacts and Outlook

Great Lakes Region

Dec. 2013 (Experimental)

Great Lakes Significant Events - for September - November 2013

There were contrasting conditions across the Great Lakes basin over the fall season, yet water levels on all the Great Lakes remained well above last year's levels and near or above chart datum throughout the quarter. The largest gain from last year has been on Lake Michigan-Huron, which is 38 cm (15 in) higher entering December compared to this time last year when it set a new record low. Nonetheless, Michigan-Huron remains well below its long-term average, whereas all of the other lakes have been within 5 cm (~2 in) of their long-term averages throughout the fall season.

Water levels on all lakes are up from this time last year. Michigan-Huron has made gains from its record lows a year ago, but remains well below average. All other lakes are near average.

A November 17th tornado outbreak that impacted IL, IN, OH, MI, and WI is now the fourth largest November outbreak in the United States.

High winds on November 17th-18th caused a wind set-up on Lake Erie, producing a 2.6 m (8.4 ft) water level difference between the western and eastern basins.

On November 16th-18th, a storm system tracked across the Great Lakes basin and brought wide-spread regional impacts including strong winds, heavy rainfall, and tornadoes. High westerly winds in excess of 111 km/hr (69 mph) pushed water on Lake Erie from one end of the lake to the other causing water levels on the west end of the lake to fall by nearly 1.2 m (4 ft), while levels on the east end at Buffalo, NY rose by close to 1.4 m (4.5 ft). At the same time, high wind gusts created large waves on eastern Lake Michigan. A rare November tornado outbreak was also associated with this system on November 17th, where there were 72 tornadoes in the U.S., some of which occurred within the Great Lakes basin. In addition, heavy rain in excess of 100 mm (3.9 in) fell over portions of northern Michigan, causing localized flooding. This type of widespread extreme event may become more common in a changing climate.

Regional Climate Overview - for September - November 2013

Precipitation

Sept. 1-Nov. 30, 2013

Precipitation: Percent of Normal (%)

During fall, the Great Lakes basin precipitation was 104% of average (based on 1900-2010). Michigan-Huron received 112% of its average fall precipitation, while Erie and Ontario received 102% of average and Superior received 91% of average. All lake basins received below-average precipitation in September, with 82% of average in the basin. In October, all lake basins received above-average precipitation, with 141% of average in the basin. November was drier than average with the exception of Michigan-Huron, with 98% of average in the basin.

Lake Surface Temperature

Sept. 1-Nov. 30, 2013

Average Lake Surface Temperature: Departure from Long-Term Average (°C)

For Sept.-Nov. 2013, departures of surface water temperatures on the Great Lakes ranged from -1.3°C (-29.7°F) to +3.4°C (+38.1°F) (compared to the long-term average from 1995-2013). Although a large portion of the lakes had a small positive deviation from the long-term average for fall (shown in gray), around 74% of the surface water temperatures were above the long-term average while 26% were below the long-term average.

Great Lakes Water Levels

Stone Lab on Lake Erie: 11/1/13
Photo: Ohio Sea Grant

The Great Lakes are typically in their period of seasonal decline during the autumn months. At the end of November, Lake Superior was 6 cm (2.4 in) below average, having fallen 10 cm (3.9 in) since the start of September, which is 1 cm (0.4 in) more than average. Wet conditions over Lake Michigan-Huron caused a decline of only 8 cm (3.1 in), compared to the usual 18 cm (7.1 in), but the lake remained 34 cm (13.4 in) below average at the end of the quarter. Both lakes Erie and Ontario fell more than normal during the quarter, but both were within 5 cm (1.2 in) of their average levels to start December.